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Endo et al.

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(54) **LASER PROCESSING APPARATUS**

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B23K 26/36	(2014.01)
B23K 26/40	(2014.01)
B23K 26/00	(2014.01)

(52) **U.S. Cl.**

CPC ***B23K 26/40*** (2013.01); ***B23K 26/0087*** (2013.01); ***B23K 26/142*** (2015.10); ***B23K 26/16*** (2013.01); ***B23K 26/364*** (2015.10); *B23K 26/36* (2013.01); *B23K 2201/40* (2013.01); *B23K 2203/50* (2015.10)

(58) **Field of Classification Search**

CPC B23K 26/00; B23K 26/16; B23K 26/36; B23K 26/364

USPC 219/121.68, 121.69

See application file for complete search history.

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(57) **ABSTRACT**

A laser processing apparatus including a dust discharging unit for discharging dust generated by the application of a laser beam from a focusing unit to a workpiece. The dust discharging unit includes a dust collector provided below the focusing unit and a suction unit connected to the dust collector. The dust collector has a U-shaped configuration composed of a rectangular top wall having an opening for allowing the pass of the laser beam applied from the focusing unit, a first side wall projecting downward from one side edge of the top wall, and a second side wall projecting downward from the other side edge of the top wall so as to be opposed to the first side wall. The suction unit includes a suction duct having one end connected to the dust collector and the other end connected to a vacuum source.

2 Claims, 6 Drawing Sheets

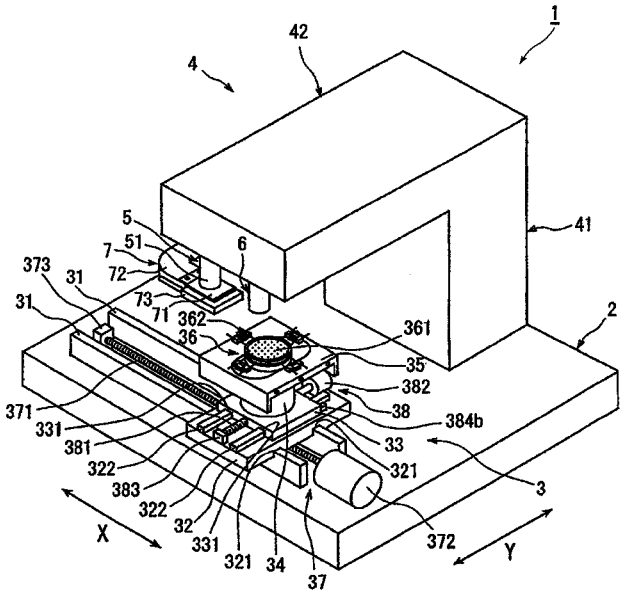

FIG. 1

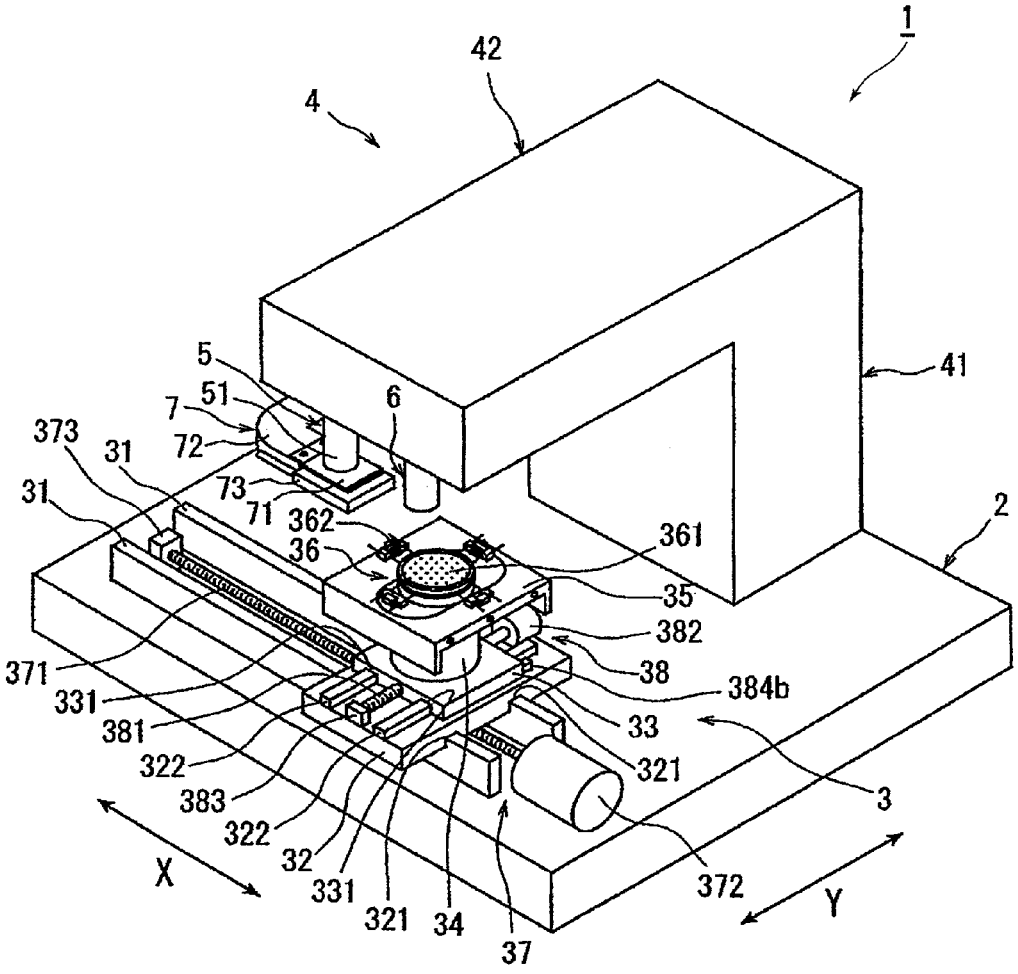
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FIG. 2

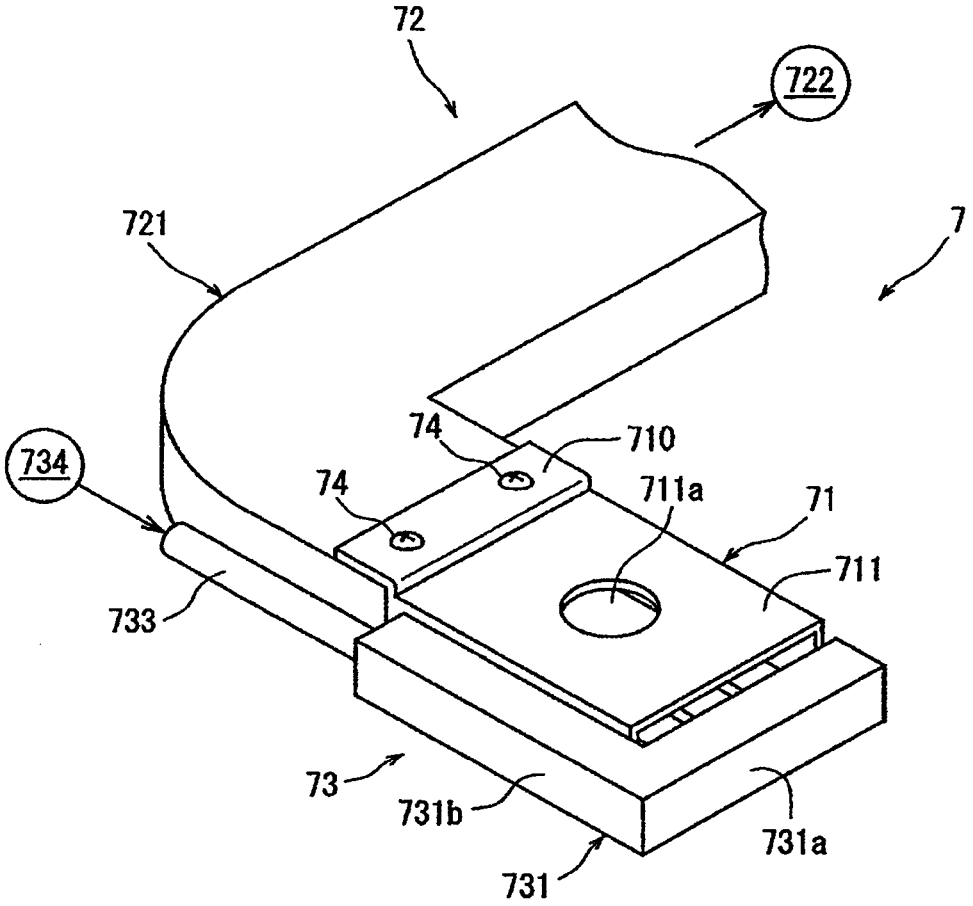

FIG. 3

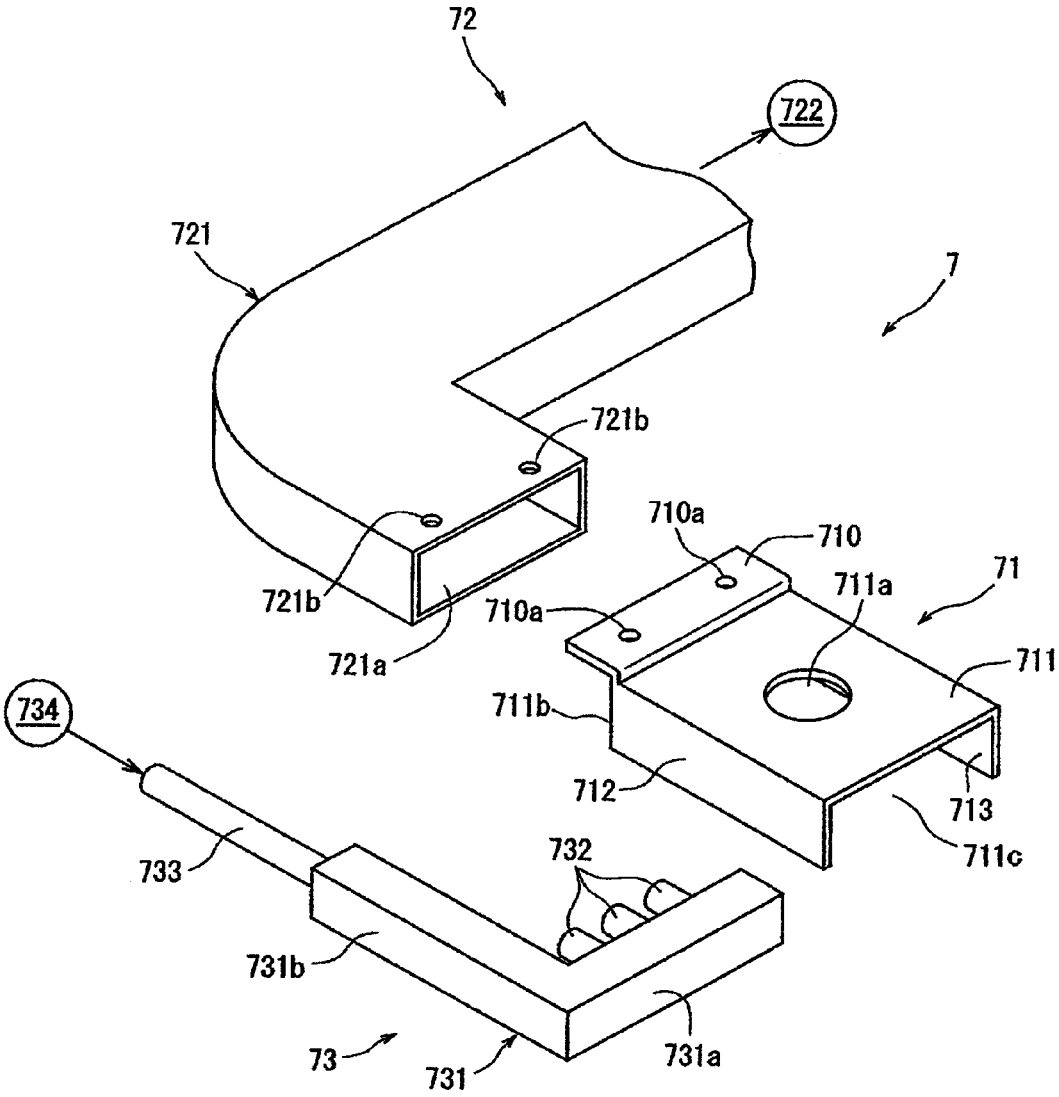
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FIG. 4

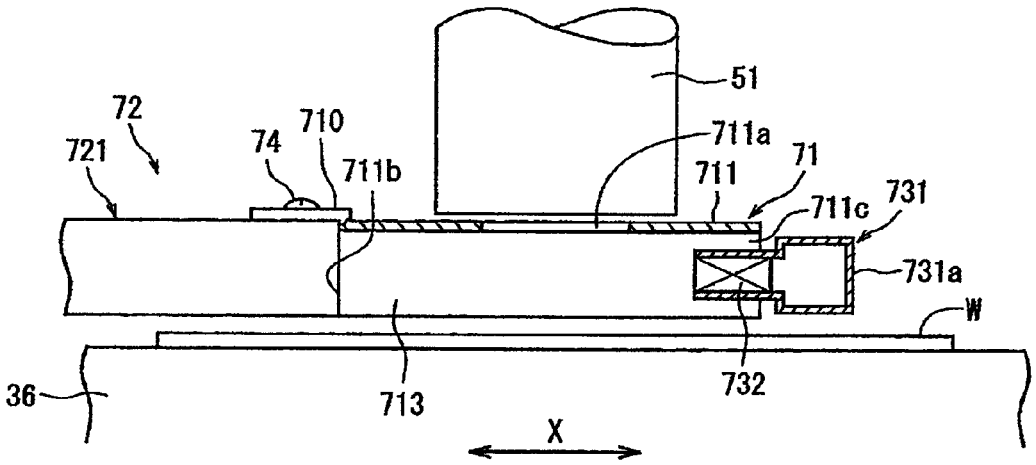


FIG. 5A

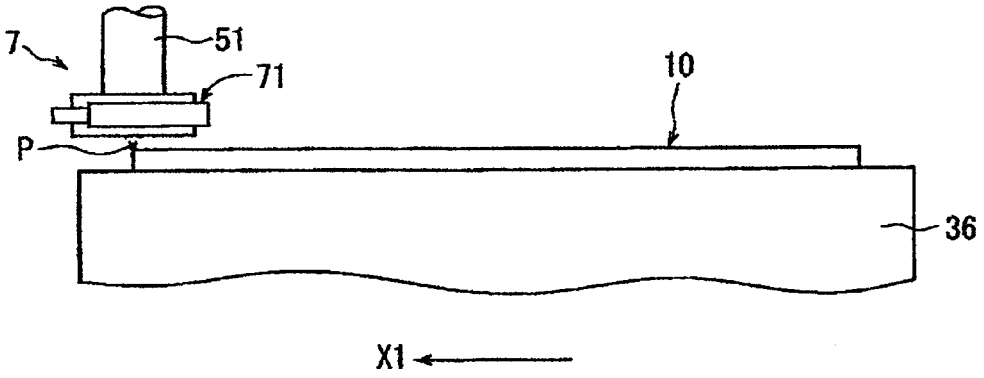


FIG. 5B

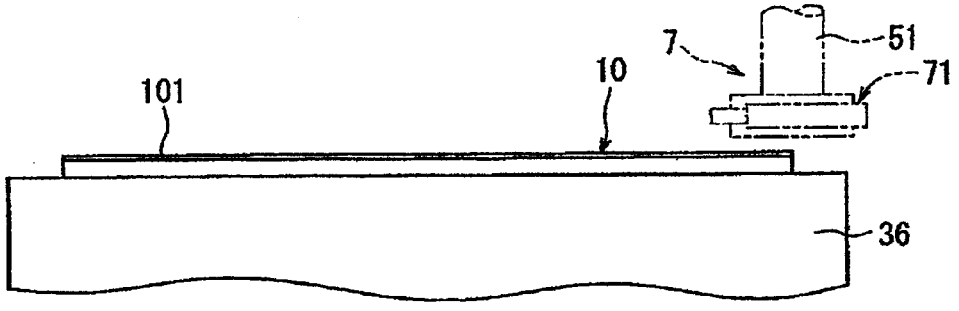
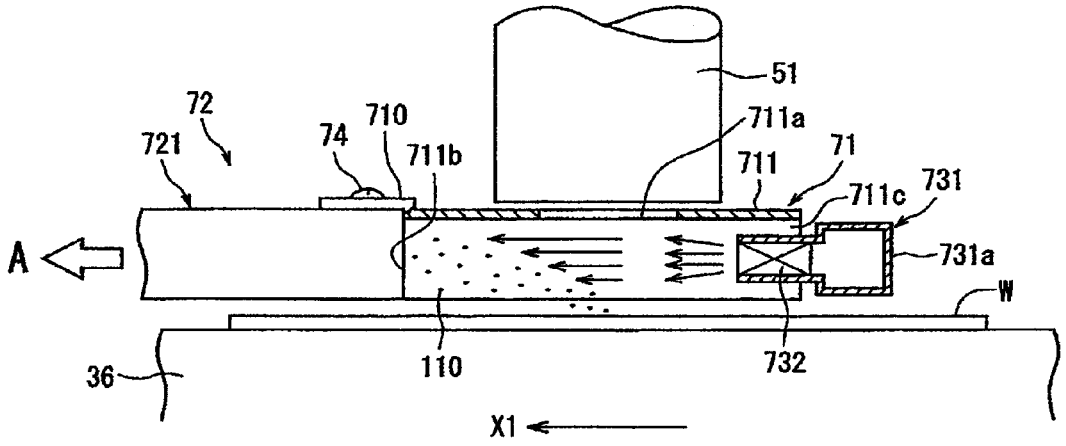


FIG. 6



LASER PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a laser processing apparatus for performing laser processing to a workpiece such as a semiconductor wafer.

2. Description of the Related Art

In a semiconductor device fabrication process, a plurality of crossing division lines called streets are formed on the front side of a substantially disk-shaped semiconductor wafer to thereby partition a plurality of regions where a plurality of devices such as ICs and LSIs are respectively formed. The semiconductor wafer is cut along the streets to thereby divide the regions where the devices are formed from each other, thus obtaining a plurality of individual semiconductor chips. Further, an optical device wafer is provided by forming a plurality of optical devices including light receiving devices such as photodiodes and light emitting devices such as laser diodes on the front side of a sapphire substrate. The optical device wafer is also cut along the streets to obtain the individual optical devices divided from each other, such as photodiodes and laser diodes, which are widely used in electric equipment.

As a method of dividing a wafer such as a semiconductor wafer and an optical device wafer along the streets, there has been proposed a method of applying a pulsed laser beam along the streets to thereby form laser processed grooves along the streets on the wafer and next breaking the wafer along these laser processed grooves.

However, when a laser beam is applied to a wafer of silicon, sapphire, etc. as a workpiece along the streets, the wafer is melted to cause scattering of melt dust, or debris, so that there arises a problem such that the dust scattered may stick to the front side of the devices formed in the rectangular regions of the wafer, causing a degradation in quality of each device. Further, there is another problem such that the dust such as debris scattered may stick to a focusing lens included in focusing means for applying a laser beam, causing the interference with the application of the laser beam.

To solve this problem, there has been proposed a laser processing apparatus including dust discharging means for collecting and discharging dust such as debris generated by the application of a laser beam to a workpiece from focusing means constituting laser beam applying means (see Japanese Patent Laid-open No. 2007-69249, for example).

SUMMARY OF THE INVENTION

In the laser processing apparatus disclosed in Japanese Patent Laid-open No. 2007-69249, the dust such as debris generated by the application of the laser beam from the focusing means to the workpiece is sucked by the dust discharging means. At this time, the dust may rise spirally along the optical path of the laser beam applied from the focusing means, so that there is a problem such that the optical path of the laser beam applied from the focusing means may be hindered by the dust, causing defective processing.

It is therefore an object of the present invention to provide a laser processing apparatus which can discharge the dust such as debris generated by the application of a laser beam from focusing means to a workpiece, without the hindrance to the optical path of the laser beam applied from the focusing means.

In accordance with an aspect of the present invention, there is provided a laser processing apparatus including: a chuck table for holding a workpiece; laser beam applying means having focusing means for applying a laser beam to the workpiece held on the chuck table to thereby process the workpiece; and dust discharging means for discharging dust generated by the application of the laser beam from the focusing means to the workpiece. The dust discharging means includes a dust collector provided below the focusing means and suction means connected to the dust collector. The dust collector has a U-shaped configuration composed of a rectangular top wall having an opening for allowing the pass of the laser beam applied from the focusing means, a first side wall projecting downward from one side edge of the top wall, and a second side wall projecting downward from the other side edge of the top wall so as to be opposed to the first side wall, whereby a first rectangular opening is formed by one end of the top wall, one end of the first side wall, and one end of the second side wall, and a second rectangular opening is formed by the other end of the top wall, the other end of the first side wall, and the other end of the second side wall. The suction means includes a suction duct having one end connected to the first rectangular opening of the dust collector and the other end connected to a vacuum source.

Preferably, the second rectangular opening of the dust collector is connected to air supplying means.

As described above, the laser processing apparatus according to the present invention includes the dust discharging means for discharging the dust generated by the application of the laser beam from the focusing means to the workpiece. The dust discharging means includes the dust collector provided below the focusing means and the suction means connected to the dust collector. The dust collector has the U-shaped configuration composed of the rectangular top wall having the opening for allowing the pass of the laser beam applied from the focusing means, the first side wall projecting downward from one side edge of the top wall, and the second side wall projecting downward from the other side edge of the top wall so as to be opposed to the first side wall, whereby the first rectangular opening is formed at one end of the dust collector and the second rectangular opening is formed at the other end of the dust collector. The suction means includes the suction duct having one end connected to the first rectangular opening of the dust collector and the other end connected to the vacuum source. Accordingly, the air in the dust collector is sucked toward the suction duct.

With this configuration, the dust generated by the application of the laser beam to the workpiece is discharged toward the suction duct with the air flowing toward the suction duct. In this manner, the dust generated by the application of the laser beam does not rise spirally, but it is discharged toward the suction duct with the air flow produced in the dust collector. Accordingly, the optical path of the laser beam applied from the focusing means is not hindered by the dust, thereby solving the problem that the dust may cause defective processing.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a laser processing apparatus according to a preferred embodiment of the present invention;

FIG. **2** is a perspective view of an essential part of dust discharging means included in the laser processing apparatus shown in FIG. **1**;

FIG. **3** is an exploded perspective view of the dust discharging means shown in FIG. **2**;

FIG. **4** is a sectional view of the dust discharging means shown in FIG. **2**;

FIGS. **5**A and **5**B are schematic side views for illustrating a laser processed groove forming step to be performed by the laser processing apparatus shown in FIG. **1**; and

FIG. **6** is a sectional view of the dust discharging means in the condition where the laser processed groove forming step shown in FIGS. **5**A and **5**B is being performed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the laser processing apparatus according to the present invention will now be described in detail with reference to the attached drawings. FIG. **1** is a perspective view of a laser processing apparatus **1** according to a preferred embodiment of the present invention. The laser processing apparatus **1** shown in FIG. **1** includes a stationary base **2**, a chuck table mechanism **3** for holding a workpiece, the chuck table mechanism **3** being provided on the stationary base **2** so as to be movable in a feeding direction (X direction) shown by an arrow X, and a laser beam applying unit **4** as laser beam applying means provided on the stationary base **2**.

The chuck table mechanism **3** includes a pair of guide rails **31** provided on the stationary base **2** so as to extend parallel to each other in the X direction, a first slide block **32** provided on the guide rails **31** so as to be movable in the X direction, a second slide block **33** provided on the first slide block **32** so as to be movable in an indexing direction (Y direction) shown by an arrow Y perpendicular to the X direction, a cover table **35** supported by a cylindrical member **34** standing on the second slide block **33**, and a chuck table **36** as workpiece holding means. The chuck table **36** has a vacuum chuck **361** formed of a porous material. A workpiece such as a disk-shaped semiconductor wafer is adapted to be held under suction on the upper surface of the vacuum chuck **361** as a workpiece holding surface by operating suction means (not shown). The chuck table **36** is rotatable by a pulse motor (not shown) provided in the cylindrical member **34**. Further, the chuck table **36** is provided with clamps **362** for fixing an annular frame supporting a workpiece such as a semiconductor wafer through a protective tape.

The lower surface of the first slide block **32** is formed with a pair of guided grooves **321** for slidably engaging the pair of guide rails **31** mentioned above. A pair of guide rails **322** are provided on the upper surface of the first slide block **32** so as to extend parallel to each other in the Y direction. Accordingly, the first slide block **32** is movable in the X direction along the guide rails **31** by the slidable engagement of the guided grooves **321** with the guide rails **31**. The chuck table mechanism **3** further includes feeding means **37** for moving the first slide block **32** in the X direction along the guide rails **31**. The feeding means **37** includes an externally threaded rod **371** extending parallel to the guide rails **31** so as to be interposed therebetween and a pulse motor **372** as a drive source for rotationally driving the externally threaded rod **371**. The externally threaded rod **371** is rotatably supported at one end thereof to a bearing block **373** fixed to the stationary base **2** and is connected at the other end to the output shaft of the pulse motor **372** so as to receive the torque thereof. The externally threaded rod **371** is engaged with a tapped through hole formed in an internally threaded block (not shown) projecting from the lower surface of the first slide block **32** at a central portion thereof. Accordingly, the first slide block **32** is moved in the X direction along the guide rails **31** by operating the pulse motor **372** to normally or reversely rotate the externally threaded rod **371**.

The lower surface of the second slide block **33** is formed with a pair of guided grooves **331** for slidably engaging the pair of guide rails **322** provided on the upper surface of the first slide block **32** as mentioned above. Accordingly, the second slide block **33** is movable in the Y direction along the guide rails **322** by the slidable engagement of the guided grooves **331** with the guide rails **322**. The chuck table mechanism **3** further includes indexing means **38** for moving the second slide block **33** in the Y direction along the guide rails **322**. The indexing means **38** includes an externally threaded rod **381** extending parallel to the guide rails **322** so as to be interposed therebetween and a pulse motor **382** as a drive source for rotationally driving the externally threaded rod **381**. The externally threaded rod **381** is rotatably supported at one end thereof to a bearing block **383** fixed to the upper surface of the first slide block **32** and is connected at the other end to the output shaft of the pulse motor **382** so as to receive the torque thereof. The externally threaded rod **381** is engaged with a tapped through hole formed in an internally threaded block (not shown) projecting from the lower surface of the second slide block **33** at a central portion thereof. Accordingly, the second slide block **33** is moved in the Y direction along the guide rails **322** by operating the pulse motor **382** to normally or reversely rotate the externally threaded rod **381**.

The laser beam applying unit **4** includes a supporting member **41** provided on the stationary base **2**, a casing **42** supported to the supporting member **41** so as to extend in a substantially horizontal direction, laser beam applying means **5** provided in connection with the casing **42**, and imaging means **6** provided at the front end portion of the casing **42** for detecting a subject area of the workpiece to be laser-processed by the laser beam applying means **5**. The laser beam applying means **5** includes laser beam oscillating means (not shown) such as a YAG laser or a YVO4 laser provided in the casing **42**, and focusing means **51** provided at the front end portion of the casing **42** adjacent to the imaging means **6** for focusing a pulsed laser beam oscillated by the laser beam oscillating means and applying this pulsed laser beam to the workpiece held on the chuck table **36**. The imaging means **6** essentially includes an imaging device (CCD). An image signal output from the imaging means **6** is transmitted to control means (not shown).

The laser processing apparatus **1** further includes dust discharging means **7** for discharging dust generated by the application of a laser beam from the focusing means **51** to the workpiece held on the chuck table **36**. This dust discharging means **7** will now be described with reference to FIGS. **2** to **4**.

The dust discharging means **7** includes a dust collector **71** provided below the focusing means **51**, suction means **72** connected to the dust collector **71**, and air supplying means **73** for supplying air to the dust collector **71**. The dust collector **71** has a U-shaped configuration composed of a rectangular top wall **711** having an opening **711***a* for allowing the pass of a laser beam applied from the focusing means **51**, a first side wall **712** projecting downward from one side edge of the top wall **711**, and a second side wall **713** projecting downward from the other side edge of the top wall **711** so as to be opposed to the first side wall **712**. As shown in FIGS. **3** and **4**, a rectangular opening **711***b* is formed by one end of the top wall **711**, one end of the first side wall **712**, and one end of the second side wall **713**. Similarly, a rectangular opening **711***c* is formed by the other end of the top wall **711**, the other end of

the first side wall **712**, and the other end of the second side wall **713**. That is, the dust collector **71** has the rectangular openings **711***b* and **711***c* at the opposite ends and is open on the lower side. A connecting portion **710** projects from one end of the top wall **711** constituting the dust collector **71** in parallel relationship with the top wall **711** in the condition where the connecting portion **710** is raised from the top wall **711** by the thickness thereof. The connecting portion **710** is formed with two bolt insertion holes **710***a*. The first side wall **712** and the second side wall **713** constituting the dust collector **71** are elongated in the X direction.

The suction means **72** constituting the dust discharging means **7** includes a suction duct **721** having one end connected to one of the rectangular openings **711***b* and **711***c* (specifically, the rectangular opening **711***b* as shown in FIGS. **3** and **4**) of the dust collector **71**. The suction duct **721** has a passage **721***a* rectangular in cross section as shown in FIG. **3**. Two tapped holes **721***b* are formed through the top wall of the suction duct **721** at one end portion thereof. These two tapped holes **721***b* are formed so as to respectively correspond to the two bolt insertion holes **710***a* of the connecting portion **710** constituting the dust collector **71**. The dust collector **71** is fixedly connected to one end of the suction duct **721** in the following manner. First, one end of the suction duct **721** is joined to the rectangular opening **711***b* of the dust collector **71**. In this condition, the two bolt insertion holes **710***a* of the connecting portion **710** constituting the dust collector **71** are respectively aligned with the two tapped holes **721***b* of the suction duct **721**. As shown in FIG. **2**, two fastening bolts **74** are inserted through the two bolt insertion holes **710***a* of the dust collector **71** and then threadedly engaged with the two tapped holes **721***b* of the suction duct **721**. As shown in FIG. **4**, the lower ends of the first and second side walls **712** and **713** constituting the dust collector **71** (only the second side wall **713** being shown in FIG. **4**) are spaced a predetermined distance from the upper surface of the workpiece W held on the chuck table **36**. In this preferred embodiment, this predetermined distance is set to 0.5 to 1.0 mm, for example. As shown in FIGS. **2** and **3**, the other end of the suction duct **721** is connected to a vacuum source **722**.

The air supplying means **73** constituting the dust discharging means **7** is composed of an air supply duct **731** having a rectangular cross section, three air diffusion filters **732** mounted on one side surface of the air supply duct **731**, and a communication duct **733** for connecting the air supply duct **731** to an air source **734**. The air supply duct **731** has an L-shaped configuration composed of a filter mounting portion **731***a* and a mounted portion **731***b*. One end of the filter mounting portion **731***a* is closed and the other end of the filter mounting portion **731***a* is connected to one end of the mounted portion **731***b*. The three air diffusion filters **732** are mounted on one side surface of the filter mounting portion **731***a* constituting the air supply duct **731**. The three air diffusion filters **732** mounted on the filter mounting portion **731***a* of the air supply duct **731** are inserted into the rectangular opening **711***c* of the dust collector **71**. In this condition, one side surface of the mounted portion **731***b* is mounted to the first side wall **712** of the dust collector **71**. The other end of the mounted portion **731***b* mounted to the first side wall **712** is connected to the communication duct **733**.

The dust discharging means **7** as configured above is operated in the following manner. The air in the dust collector **71** is sucked through the suction duct **721** connected to the vacuum source **722** at a suction rate of 1 m^3/min. On the other hand, air is supplied from the air source **734** through the communication duct **733**, the air supply duct **731**, and the three air diffusion filters **732** into the dust collector **71** at a supply rate of 0.7 m^3/min.

The operation of the laser processing apparatus **1** configured above will now be described. As shown in FIG. **5**A, a semiconductor wafer **10** as a workpiece is placed on the chuck table **36** of the laser processing apparatus **1** and the suction means (not shown) connected to the chuck table **36** is operated to hold the semiconductor wafer **10** on the chuck table **36** under suction. Although not shown, a plurality of crossing streets are formed on the front side of the semiconductor wafer **10** to thereby partition a plurality of regions where a plurality of devices such as ICs and LSIs are respectively formed. The chuck table **36** holding the semiconductor wafer **10** under suction is moved to a position directly below the imaging means **6** by the feeding means **37**. When the chuck table **36** is positioned directly below the imaging means **6**, an alignment operation is performed by the imaging means **6** and the control means (not shown) to detect a subject area of the semiconductor wafer **10** to be laser-processed. More specifically, the imaging means **6** and the control means (not shown) perform image processing such as pattern matching for making the alignment of the streets extending in a first direction on the semiconductor wafer **10** and the focusing means **51** of the laser beam applying means **5** for applying the laser beam along these streets, thereby performing the alignment of a laser beam applying position. This alignment operation is performed similarly for the other streets extending in a second direction perpendicular to the first direction.

After performing the alignment operation for all of the streets formed on the semiconductor wafer **10** held on the chuck table **36**, the chuck table **36** is moved to a laser beam applying area where the focusing means **51** of the laser beam applying means **5** is located as shown in FIG. **5**A. Further, one end (left end as viewed in FIG. **5**A) of a predetermined one of the streets is positioned directly below the focusing means **51**. Thereafter, the focal point P of the pulsed laser beam to be applied from the focusing means **51** is set near the front side (upper surface) of the semiconductor wafer **10**. Thereafter, the pulsed laser beam having an absorption wavelength to the semiconductor wafer **10** is applied from the focusing means **51** of the laser beam applying means **5**, and the chuck table **36** is moved in the direction shown by an arrow X1 in FIG. **5**A at a predetermined feed speed. When the other end (right end as viewed in FIG. **5**B) of the predetermined street reaches the position directly below the focusing means **51** as shown in FIG. **5**B, the application of the pulsed laser beam is stopped and the movement of the chuck table **36** is also stopped. As a result, a laser processed groove **101** is formed along the predetermined street on the semiconductor wafer **10** as shown in FIG. **5**B (laser processed groove forming step).

For example, the laser processed groove forming step mentioned above is performed under the following processing conditions.

Light source of the laser beam: YVO4 pulsed laser or YAG pulsed laser
Wavelength: 355 nm
Repetition frequency: 50 kHz
Average power: 4 W
Focused spot diameter: 20 pm
Work feed speed: 150 mm/s

In the laser processed groove forming step mentioned above, the pulsed laser beam is applied from the focusing means **51** to the front side of the semiconductor wafer **10**, so that the semiconductor wafer **10** is melted to generate dust such as debris. However, the laser processing apparatus **1** includes the dust discharging means **7** for discharging the dust

generated from the semiconductor wafer **10**. That is, as shown in FIG. **6**, the air in the dust collector **71** is sucked toward the suction duct **721** as shown by an arrow A at a suction rate of 1 m^3/min. At the same time, air is supplied through the air supply duct **731** and the three air diffusion filters **732** into the dust collector **71** at a supply rate of 0.7 m^3/min. Accordingly, dust **110** generated by the application of the pulsed laser beam to the semiconductor wafer **10** is discharged toward the suction duct **721** with the air flow shown by the arrow A. In this manner, the dust **110** generated by the application of the pulsed laser beam does not rise spirally, but it is discharged toward the suction duct **721** with the air flow shown by the arrow A. Accordingly, the optical path of the pulsed laser beam applied from the focusing means **51** is not hindered by the dust **110**, thereby solving the problem that the dust **110** may cause defective processing.

The present invention is not limited to the details of the above described preferred embodiment. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

What is claimed is:

1. A laser processing apparatus comprising:

a chuck table for holding a workpiece;

laser beam applying means having focusing means for applying a laser beam to the workpiece held on the chuck table to thereby process the workpiece; and

dust discharging means for discharging dust generated by the application of the laser beam from the focusing means to the workpiece;

said dust discharging means including a dust collector provided below the focusing means and suction means connected to the dust collector;

the dust collector having a U-shaped configuration composed of a rectangular top wall having an opening for allowing the pass of the laser beam applied from the focusing means, a first side wall projecting downward from one side edge of the top wall, and a second side wall projecting downward from the other side edge of the top wall so as to be opposed to the first side wall, whereby a first rectangular opening is formed by one end of the top wall, one end of the first side wall, and one end of the second side wall, and a second rectangular opening is formed by the other end of the top wall, the other end of the first side wall, and the other end of the second side wall;

the suction means including a suction duct having one end connected to the first rectangular opening of the dust collector and the other end connected to a vacuum source.

2. The laser processing apparatus according to claim **1**, wherein the second rectangular opening of the dust collector is connected to air supplying means.

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